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Environmental Contamination of Soils by Cadmium, Associated with Former Zn-Pb Ore Mining Activity in the Upper Silesia Region (southern Poland)

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Due to the fact that Cd is classified as a potentially harmful element with respect to soil biological activity, plant metabolism and the health of humans and animals, there is concern over anthropogenic accumulations of Cd in the environment. It has no essential biological function, but it tends to accumulate in plants and aquatic biota, with consequent problems of toxicity. It is toxic to humans through the inhalation of dust, causing lung damage, and may cause cancer from long-term exposure, being also teratogenic and embryocidal.

As soil is the main disposal and landfill receptor for different types of wastes, it is of great importance to carry out research, which provides the necessary data on the element content in the Earth's surface materials. Systematic geochemical mapping is a very effective tool of showing the geographical distribution of the elements, and environmental geochemical baseline data are urgently required to inform policy-makers and to provide a sound basis for environmental legislation and resource management.

The study area is located in southern Poland (in the Polish part of the Upper Silesian Coal Basin). It is a part of the Palaeozoic Variscan structure cut by numerous faults. The stratigraphic section is represented by the Triassic, Neogene and Quaternary systems (Wilanowski *et al*., 2009). The deposits of Zn and Pb ores, exploited in the past occurring in the Triassic ore-bearing dolomite were characterised as the largest and richest Zn and Pb ore deposits in the world (Szuwarzyński, 1996; Viets *et al*., 1996; Paulo and Strzelska-Smakowska, 2000). For many years, the most important sectors in the study area were coal mining and Fe metallurgy, as well as Zn metallurgy in the past. The analysed area shows a diverse relief, locally highly modified as a result of industrial activity. There are many landfills of slag and mining waste near historical and present-day metal smelters.

Since 1996, a detailed geochemical mapping project for this region (scale 1:25,000) has been conducted by the Polish Geological Institute. Until 2019, 17 map sheets have been completed and published in the form of separate atlases. The main objectives of this project were the investigation of the environmental impacts of industry on soil contamination by potentially hazardous elements (including Cd) and assessment of the degree of soil contamination.

The obtained research results allowed determination of the geochemical baseline of Cd in the region, controlled by natural factors, and indication of anthropogenically contaminated areas. The anthropogenic factors were associated mainly with former mining, processing and metallurgical industry of Zn-Pb ore, Fe smelting, as well as hard coal mining and energy industry.

The study was performed on soil samples from two depth intervals: 0−30 cm (topsoil 22,663 samples) and 80−100 cm (subsoil 19,307 samples), collected with a density grid of 16 samples/km^2. Content of Cd in soil was determined by the inductively coupled plasma optical emission spectroscopy (ICP-OES) after sample digestion in hot *aqua regia* solution.

Analysed topsoil samples had a wide range of such properties as pH (from very acidic to alkaline), TOC content (0.05–55.9%) and particle size distribution (from sandy to clay soil) showed their significant transformation. Anthropogenic transformations have led to so significant changes in the chemical composition of the soil in relation to the parent rocks that the basic geochemical features of the original rocks in the topsoil are very poorly visible. In areas of mining activity, around historical and modern metallurgical plants, as well as near mine heaps and waste dumps there are numerous anthropogenic anomalies of Ag, As, Cd, Cr, Cu, Fe, Hg, Ni, Pb and Zn. The obtained results indicated great variation in Cd content in topsoil (<0.5–2,107 mg/kg; mean 4.3 mg/kg) and subsoil (<0.5–747 mg/kg; mean 2.2 mg/kg). Strong anomalies for Cd (Fig. 1), as well as for Ag, As, Pb and Zn, are observed in the areas of historical Zn-Pb ore mining, former Zn smelters, and modern Fe industry. About 25% of topsoil samples contained more than 4 mg/kg of Cd (Pb >144 mg/kg and Zn >419 mg/kg). About 25% of subsoil samples contained more than 0.7 mg/kg of Cd (Pb >33 mg/kg and Zn >101 mg/kg).

The anthropogenic pollution sources in the natural environment encompass metallurgy of Fe and non-ferrous metals, chemical and metal industries, mining of coal and its large-scale burning in power plants, historical exploitation and smelting of Pb-Zn ore, the impact of industrial waste (heaps of gangue and slag, settling ponds for sludge coal mud, mine water discharges), urbanisation and transport.

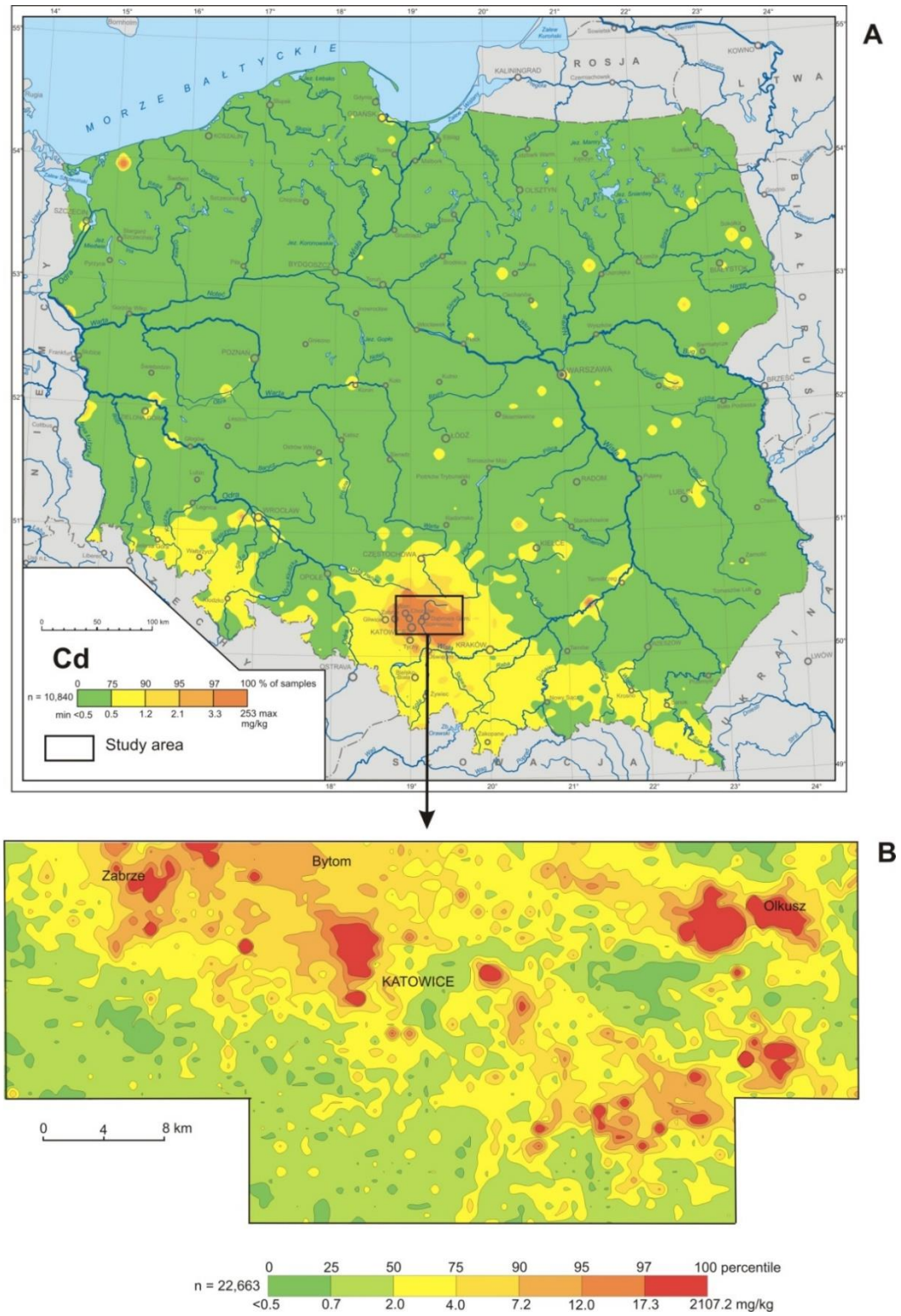

Figure 1. Cadmium content in topsoil samples (0-30 cm) of Poland (A) and Upper Silesia Region (B).

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